Case report

Effects of a fifty-six month electrical stimulation cycling program after tetraplegia: case report

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Background: Functional electrical stimulation cycling is a common clinical treatment for individuals with spinal cord injury and other paralytic conditions, however, the long term effects of home-based functional electrical stimulation cycling remains unreported.
Objective: To determine the effectiveness of a long-term home-based functional electrical stimulation lower extremities cycling (FES-LEC) program on body composition.
Participant: An adult male 52.7 years of age at pre-intervention and 57.3 years of age at post-intervention with chronic C4 spinal cord injury and American Spinal Injury Association Impairment Scale C.
Methods: Dual-energy X-ray absorptiometry scans were performed on the participant before and after the FES cycling program to determine body composition changes. An RT300 FES cycle was issued to the participant with the recommendation to cycle three times per week for general conditioning and the maintenance of physical health.
Results: Total body lean mass (LM) increased from 39.13 kg to 46.35 kg, an 18.5% increase while total body fat mass (FM) increased by just 3.7% from 20.85 kg to 21.64 kg. Legs LM increased by 10.9% (10.93 kg to 12.12 kg). There was a negligible decrease in total body bone mineral content (BMC) with a pre-training measure of 2.09 kg compared to a post-training measure of 1.98 kg. Lower extremities FM increased by less than 1% from 3.51 kg to 3.54 kg.
Conclusion: Natural limitations of a single subject case report disallow a causal conclusion. However, for this particular older adult with chronic tetraplegia, home-based FES-LEC appears to have resulted in cardio-metabolic protective body composition changes.

Keywords: Tetraplegia, Functional electrical stimulation cycling, Body composition

Introduction

Sedentary lifestyle is a well-established risk factor for cardio-metabolic diseases and all-cause mortality.[1] This is especially true for individuals with mobility related disabilities. The physical activity levels of individuals with spinal cord injuries (SCI) have been reported to be only 40% of that of the general population.[2] According to a survey conducted by the Centers for Disease Control and Prevention (CDC), there are more than 21 million adults with disabilities living in the U.S., of which half of them participate in no aerobic physical activity.[3] These individuals are three times more likely to suffer health conditions such as heart attack, stroke, diabetes, or cancer compared to adults without disabilities.[3] Evans *et al*.[4] recommend that individuals with SCI complete moderate to vigorous aerobic exercises and muscle strengthening activities twice weekly and stretching/range of motion activities of major joints daily. While individuals with disabilities effecting physical mobility are typically considered among the most sedentary, a recent study demonstrated that if provided the opportunity, individuals with significant disabilities are able to adhere to regular exercise regimes.[5]

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DOI 10.1080/10790268.2016.1234750

Adverse body composition changes such as decreased muscle mass and increased fat mass have been associated with cardio-metabolic disease risk in individuals with SCI.[6–10] Functional electrical stimulation lower extremity cycling (FES-LEC) has been shown to provide at least partial restorative effects of healthy body composition. Skold *et al.*[11] and Mohr *et al.*[12] found increased skeletal muscle cross sectional area and muscle mass after two to three FES-LEC sessions per week for 6 and 12 months respectively. Likewise, a series of case reports resulted in healthy body composition changes (increased muscle mass and decreased body fat percentage) in older adults after FES-LEC regimes of 9 weeks, 6 months and 12 months.[13–15] The purpose of this case report was to determine the effects of FES-LEC cycling on body composition after home-based training for 56 months.

Case report

Participant

An adult male with chronic C4 American Spinal Injury Association (ASIA) impairment scale classification C participated in fifty-six months of FES-LEC. The non-ambulatory participant was 52.7 years of age at the start of the home-based FES cycling program and 57.3 years of age at the completion of the program. The participant was 33 years post-injury at the onset of the FES-LEC regime. The participant was 1.73 m in height and 63.14 kg in weight at the start of the FES-LEC program. The participant's body mass index (BMI) was 21.6 kg/m^2 and with no prior history of participation in a regular exercise program prior to the study.

The participant underwent a medical examination by a SCI physician after which a medical prescription for FES-LEC was provided. The participant then reviewed and completed an informed consent document. The individual underwent training concerning the safe operation of the FES cycle and the initial FES-LEC training session was performed in the SCI exercise laboratory at the McGuire VA Medical Center, Richmond, VA. This was in order to ensure that the participant was able to safely tolerate the activity and acquire baseline parameters concerning cycle speed, resistance, electrical stimulation intensity, frequency and pulse width. Likewise, the participant received instruction concerning electrode placement on the quadriceps, hamstrings and gluteal muscles. An RT300 FES cycle (Restorative Therapies Inc, Baltimore, MD, USA) was placed in the participant's home with internet connection so that the exercise performance of each cycling session could be reviewed by trained technicians. A Lunar Prodigy Advance Dual-Energy X-Ray Absorptiometry (DXA) scanner (General Electric, Madison, WI, USA) was used to measure body composition prior to and after the 56 months of FES-LEC. A ceiling mounted mechanical lift was used to transfer the participant from the wheelchair to the DXA and then back to the wheelchair after the DXA scan was completed. The participant was positioned supine with legs strapped together for safety in the event of muscle spasms.

The participant was instructed to gradually increase the duration of the cycling sessions until he was able to perform FES-LEC for 40–60 minutes. It was recommended that the participant cycle three times per week. The cycling speed was set for comfort and cycling efficiency and varied between 40 to 50 revolutions per minute over the 56 months. The resistance was set to automatically decrease if the participant was unable to maintain the selected speed. The default resistance was set at 0.5 Nm, however the average resistance increased as the participant's physical conditioning improved. The average resistance for the cycling sessions reached as high as 2.0 Nm. Electrical parameters were maintained as follows: electrical intensity 120–140 mA, frequency 33.3–35.7 Hz, and pulse width 250–300 μs.

Results

The participant performed 413 FES-LEC separate day sessions over 56 months for an average 7.37 sessions per month or 1.72 sessions per week. Several changes in body composition were demonstrated via DXA measurements (Table 1). The participant's body weight increased by 10.3% from 63.14 kg to 69.67 kg. However the body fat percentage (BF%) dropped from 34.8% to 31.8% due to an increase in lean mass (LM) over the 56 months. Total body LM increased from 39.13 kg to 46.35 kg, an 18.5% increase while total body fat mass (FM) increased by just 3.7% from 20.85 kg to 21.64 kg. There was a 2% decrease in trunk fat mass from 14.75 kg to 14.39 kg. Legs LM increased by 10.9% from 10.93 kg to 12.12 kg. Lower extremities FM increased by less than 1% from 3.51 kg to 3.54 kg. There was a small decrease in total body bone mineral content (BMC) with a pre-training measure of 2.09 kg compared to a post-training measure of 1.98 kg. Bone mineral density (BMD) estimated from the BMC of the DXA scan was also essentially maintained with a pre-intervention measurement of 1.024 g/cm^2 and a post-intervention measurement of 1.018 g/cm^2. During the more than four and a half years in which FES-LEC was performed, no major illnesses or injuries were reported.

Table 1 Changes in body composition following 56 months of FES-LEC

	Wt (kg)	LM (kg)	FM (kg)	Legs LM (kg)	Legs FM (kg)	BMD (g/cm^2)
Pre-cycling	63.14	39.13	20.85	10.93	3.51	1.024
Post-cycling	69.67	46.35	21.64	12.12	3.54	1.018
% change	10%	18.5%	4%	11%	< 1%	< 1%

Discussion

The increase in body weight of 6.5 kg was explained by the 7.2 kg increase in LM. There was a 4% increase in whole body FM but a 2% decrease in trunk FM and legs FM increased by less than 1%. An indication that at least part of the increased LM was due to increased legs muscle mass was the 10.9% increase in legs LM from 10.93 kg to 12.12 kg.

Mahoney *et al.*[16] demonstrated that neuromuscular electrical stimulation resistance exercise conducted twice weekly for 12 weeks is able to produce a 35% increase in cross sectional area of the quadriceps femoris muscle in individuals with chronic SCI. The current case study supports the results of Mahoney and associates, as the participant in this case report demonstrated a 10.9% increase in legs LM after performing FES-LEC 1.72 times per week on average for 56 months.

Typically, bone mass is thought to decrease with age, however, the older male participant in this case study was essentially able to maintain bone mass over a 56-month period. BMC decreased from 2.09 kg to 1.98 kg which can be considered negligible. Additionally, bone mineral density (BMD) estimated from the BMC of the DXA scan was also maintained with a pre-intervention measurement of 1.024 g/cm^2 and a post-intervention measurement of 1.018 g/cm^2. The bone mass T-score as calculated by DXA did not change between pre- and post-intervention measurements, both producing a T-score of –2.5.

The authors would like to point out that this participant was classified as AIS C which indicates that individuals beyond AIS A and B may benefit from long term FES-LEC.

Additionally, in persons with AIS C, spasticity may be an integral component for maintaining skeletal muscle mass and size which could also explain some of the LM values. Previously, we have shown that individuals with incomplete SCI and spasticity have experienced 22% greater muscle size than persons with incomplete SCI without spasticity.[17] Moreover, spasticity may contribute to improvement in muscle quality as characterized by reduction in intramuscular fat that may serve as an insulator to the progression of the electrical current.[17,18] This may allow persons with incomplete AIS C to have better tolerance to FES current.

Finally, the current case report supports the assertion that twice weekly FES-LEC may be beneficial in regard to changes in body composition in individuals with SCI.

Limitations

This study is a report of a single older adult male with chronic tetraplegia, thus the results are unable to be generalized to the overall population of adults with tetraplegia. More precisely, these results demonstrate the changes produced in this individual after 56 months of FES-LEC.

Conclusion

This case study reported desirable changes in body composition in an older adult with chronic tetraplegia after 56 months of FES-LEC. The demonstrated increase in total body LM appears to be at least in part due to the FES-LEC intervention as the paralyzed legs also increased in LM by 10.9%. Likewise, BMD was maintained over this extended period of time as well. Because this is a case report involving one individual, we are unable to report a causal conclusion. However, for this older adult with chronic tetraplegia, home-based FES-LEC appears to have resulted in cardio-metabolic protective body composition changes.

Disclaimer statements

Contributors None.

Funding None.

Conflict of interest The authors of this manuscript have no conflicts of interest to report.

Ethics approval None.

Disclosures None.

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